published some time ago a beautiful book, to the excellence of which we bore willing and honest testimony. It is the selection of examples which we mainly condemn in the work now before us, and as it is just possible that with this he may have had nothing to do, this admission is due to him. If we understand rightly, no copies of this first part have been issued to the public, and we would express an earnest hope that none will be. For the credit of the Government School of Design let it be cancelled forthwith.

ON THE GEOMETRICAL LINES AND OPTICAL CORRECTIONS OF THE GREEK ARCHITECTS.*

I now proceed to that part of the subject which is more particularly the object of the present paper, namely, the optical corrections. I shall first state the case as I found it, and lastly, say a few words on the probable origin and intention of these subtleties, which prevail, more or less, in almost all the Greek temples. In all, indeed, that I have examined, with the exception of the Temple of Bassæ, on the borders of Arcadia, where I could not find satisfactory indication of either convexity of pavement, or inclination of the columns, or even entasis.

The pavement of the Parthenon is bounded by four curved lines, viz., the edges of the upper step on the four sides of the building. The four angles of this curved surface are not precisely level, the south-west angle is about ·16 above the north-east and south-east angles. I think that this is simply owing to the lines of the earlier temple, which were also curved, being made use of as far as they would go, and by being produced in one direction only, and remaining fixed at the south-west angle. The line so produced would naturally fall below the fixed point.

This is the case on the west front, south, and north sides. The extreme points of the upper step of the east front are exceedingly near level.

The result of a number of observations gives only a difference of ·002, or $\frac{1}{500}$ feet, a quantity which we need not stop to discuss.

If these two points be joined by a straight line, the curve which forms the edge of the step will be found under the middle columns to rise to a height of ·214 above it. If the uniform curve had been preserved, it would have been ·218 in the middle, which is about $\frac{1}{230}$ breadth of front; and the curvature is so regular on the northern half of this front, where the steps rise immediately from the solid unbroken rock, and consequently no settlement can have taken place, that of four points measured at the centres of each column, three agree exactly with a circular arc: the fourth differs only by ·003. The curvature is so very slight that it might be any regular continuous curve; for instance, in so small an arc no appreciable difference could be shewn between the arc of a circle or that of an ellipse or parabola, and I think that the work was set out by means of the latter figure, which might be done very easily; whereas, I need scarcely point out the difficulty, or rather impossibility, of using the circle, which would require a diameter of about 2½ miles.

Let it be required to construct a circular or other arc of uniform curvature, whose length is 100 feet, and the rise at the centre is to be ·25, or any other small measure which must not much exceed one foot.

Construct with any axis a parabola, and set off from the vertex AB = the proposed rise, and draw LM at right angles with AB.

Now, LM will represent the 100 feet horizontally, and ordinates drawn to the curve perpendicular to LM will determine the exact rise at as many points as may be required, full size.

The curve on the upper step north side of the Parthenon, also approximates to a regular curve very closely; its entire rise in the centre above the line joining its extreme parts, is ·356, which is very nearly in the proportion of ⅘ of the rise in the east front: it is exactly $\frac{1}{450}$ length of the building.

The curve on the south side seems to have been identical with the north side, but it has suffered more from the concussions which the building has undergone, especially as there is a great depth required on this side of artificial foundation. On the north side the steps rise almost immediately from the solid rock. The curve on the west front is not quite so symmetrical as the other sides. It has, I believe, been affected by the lines of the old building. The rise is exactly the same as the east end.

The upper members on all four sides follow the steps, and are nearly parallel, but there is a little more curvature given to the steps; the entire rise of architrave is ·173 on east front, ·175 on west. The levels of those portions of the entablatures which remain on the north and south sides point out the directions which those lines had originally, and they were as nearly as possible parallel to the line of the step, excepting that just at the angle columns the step has a little the more declension. The frieze and cornice are exactly parallel with the architrave. In the Temple of Theseus, also, these curves prevail; on the fronts the rise is $\frac{1}{100}$ part of its length, on the flank $\frac{1}{170}$. The lines in the architrave are exactly parallel to the step.

There is one refinement which the Temple of Theseus possesses which the Parthenon is without. In addition to the cornice being raised, the inclined lines of the pediment have a very slight convexity, between ·02 and ·03. I was unable to fix more precisely the amount. I imagine that it was owing to some degree of haste, in which the Parthenon was finished, of which there are several indications in the upper members, which prevented this final adjustment being made to its pediments. The state of the political horizon at that time making the completion of the long walls of more immediate importance than the optical corrections of the Parthenon. On a former occasion, when I read a paper to this institute, I stated my impression that the cause which led to the adoption of this convexity of the horizontal lines, existed in the contrast of the inclined lines of the pediment.

Mr. Ferguson, who has, I understand, promised to read us a paper on Indian architecture next evening, has kindly favoured me with an illustration, which I will read to you, from a description of the construction of an iron foundry at Kasipur, near Calcutta, built in the year 1834. The foundry is covered by a single roof, with principal rafters, tie rods, and suspension bar, from the centre. The rise is 6 feet and the span 50 feet, which is exactly the same pitch as the Parthenon and Propylæa. The passage is extracted from the fourth volume of the journal of Asiatic Society of Bengal, page 116.

"Before closing our short account of Kasipur roof, we must notice a curious optical deception, for which we are somewhat at a loss for a correct explanation. On entering the room and looking up at the roof, it strikes every beholder that the roof has somewhat sunk, and the horizontal tie rod is about 5 or 6 inches lower in the centre than near the walls.

So firmly impressed were we of this being the case, that standing at one end of the room, and holding two flat brass rulers, over-lapping one another, to the eye, we could readily measure the apparent angle of the tie rod, by raising the ends of the rulers so as to coincide with the two halves of the tie rods.

On mounting the roof and looking in at the upper window at either end, the same effect was still visible, though in a diminished degree, and we were not convinced that it was a deception until Major Hutchinson, at our request, caused an actual measurement to be made by a perpendicular wooden batten from an accurately adjusted level on the stone floor. It was then proved that there did not exist a difference of level even to the tenth of an inch." The writer's manipulation of the brass rulers I do not pretend to understand, but the conclusion is obvious that a straight tie-rod appeared to be deflected; and I have no hesitation whatever in ascribing the cause to the contrasting lines of the principal rafters. I do not think that it is necessary to have our eyes refined by a southern climate for the appreciation of these effects. I suppose that there are very few gentlemen here who have not felt the same disagreeable effect of a flat open roof with horizontal tie-beams, unless, indeed, the latter be very much cambered. That this was the view the ancients took of the matter I am convinced by these two facts—

That the great temple at Pæstum has the convexity only in its fronts, and not on its flanks; and in the Propylæa at Athens, although the base on which the columns of the two pediments stand is perfectly straight and level, the line of the architrave was curved. For enough remains to determine this in the eastern portico—the central columns are actually about ·12 higher than those at the angles. The base in this building is cut in two by the ascending roadway, so that there could have been little or no advantage in a convex base line.

It will be well to remember that the temples at Athens were the result of the experience of several centuries in which these refinements were gradually brought to perfection.

The first process was probably to raise the cornice under the pediments and entablature by making the middle columns a little higher than those towards the angles, as I have mentioned in the case of the Propylæa. Still it is likely that to a fastidious eye the straight line of the stylobate would appear weak.

The second method would be that found in the great temple at Pæstum, in which the fronts have the convexity in their steps, as well as their entablatures, the flanks being composed with horizontal lines. Perhaps a reasonable man should be content with this. I must willingly admit that I was perfectly content with the temple at Pæstum; still nothing short of perfection could satisfy the refinement of vision with which the Greeks alone, among the people of all time, seem to have been endued; and perhaps by looking at a temple constructed as above-mentioned, anglewise, and contrasting the convexity of the corona of the fronts with the straight line of that on the flanks, or more likely the comparison of the two different forms of line on the stylobate, suggested the possibility of improvement; at any rate as early as the time of Pisistratus, the Athenians had begun to demand from their architects the perfected construction, as the foundations of the Temple of Jupiter Olympus testify, which we know were laid during his reign.

I also refer to his time, the earlier Temple of Minerva, which occupied the site of the Parthenon at the time of the Persian invasion, in which also we find that the lines on the four sides of the building were convex. I can bear witness also to convexity on all the four sides of the temple at Nemæa, in the Peloponesus, and Segeste, in Sicily. I could find no trace of convexity at Corinth, Egina, Rhamnus, or Bassæ.

The next subject is the inclination of the columns and the upright faces of the building.

1st. The face of the steps inclines about ·008.

2nd. The columns incline, backwards, a quantity, of which I obtained the following results. From the average of the measurements of all the lower drums, (scamillæ impares, as Vitruvius calls them) ·229. From plumbing the angular columns of the east front, taking into consideration all the cracks and movements which have modified its original position, I obtain two results of ·230 and ·232.

In the plumbing, I observed every precaution to ensure correctness, using a very heavy weight and also watching for calm intervals of weather, which are rare at Athens. I am disposed to think that ·228, or one thousandth part of the length of the building was the amount originally intended. Those gentlemen who remember the perfection of the joints with which the Parthenon is constructed, will allow that the openings between them, which at present exist, are the exact records of all the settlements which the building has undergone, and that by a careful examination of these, the original amounts may be exactly recovered, which would be hopeless in a building which had been of less highly-finished construction.

Vitruvius directs that the columns of the Pronaos and Posticum should be set perpendicular, and those of the Peristyle should incline towards the cella.

In Cicero ad Verrem, we have an amusing passage, in which Cicero relates one of his rascalities; that having under his charge, as Roman governor, a young Syracusan nobleman, whose property was subject to the con-

* See page 112, *ante*.